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The Hidden Challenges of Team Tutor Development

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INTRODUCTION

This paper describes the unexpected challenges of team tutor development such as the task and logistics. Previously, a research team from Iowa State University (ISU) working with the U.S. Army Research Laboratory (ARL) developed the reconnaissance (Recon) task for simple team tutoring with the Generalized Intelligent Framework for Tutoring (GIFT) (Bonner et al., 2015; Gilbert et al., 2015). Considerations were included for the testing environment such as audio-based team interactions, initialization of the scenario simultaneously, and the inclusion of eyetracking and screen capture technology. Throughout the process of tutor development, several computational challenges have been encountered such as the implementation of team rules, determination of the appropriate amount of feedback, and the use of participants' behavior history as input to the tutor. Our descriptions of these challenges should forewarn future developers of team tutors. We also suggest enhancements to GIFT to aid this process.

Surveillance Task Development

The surveillance task was developed by using Virtual Battle Space 2.0 (VBS2) (see Figure 11). Surveillance was chosen as the military subject matter due to its scalability in large or small team environments. The task's purpose was to serve as a testbed for examining different dimensions of feedback (Bonner et al., 2015). In the task, two learners operate avatars atop a roof and are responsible for surveillance of the entire area. This surveillance consists of completing four subtasks: 1) scan their individual area, 2) identify opposing force avatars (OPFOR), 3) transfer responsibility for tracking OPFOR to a teammate, and 4) acknowledge a transfer from a teammate.

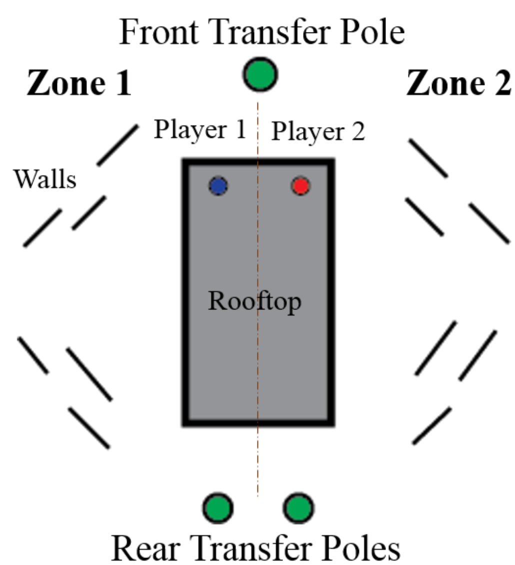

Figure 11: Surveillance Scenario Layout

Currently, the scope of the work has focused on the subject of feedback. Feedback is provided based on subtask performance (Table 1). Several GIFT conditions were developed which are further explained in Bonner et al. (2015) and Walton et al. (2015a). The conditions are also informed by work detailed in Walton et al.'s (2015b) work with the *Team Multiple Errands Task (TMET),* which deals with a team-based shopping task.

Table 2: Subtasks Performed by Learners

Sub Task	**Task Description**
Scan	The learner rotates the viewpoint within their 180 degree sector continuously throughout the task
Identify	The learner presses a key whenever spotting a new OPFOR avatar.
Transfer (notify)	When an OPFOR avatar is close to moving into a teammate's assigned sector, the learner must inform the team member.
Transfer (acknowledge)	The learner must acknowledge transfer of responsibility for the incoming OPFOR from the teammate who initiated the transfer process.
Measures	**Capture Method Description**
Degree of Scan	The position of the learner's viewpoint must pan the full 180 degrees of their assigned sector every 10 seconds; if not, feedback will be sent to them via GIFT and recorded via log files
ID Button Press	Button press logs will show if the ID key was pressed within 10 seconds of each individual OPFOR appearance
Transfers	Button press logs will show if the transfer key was pressed at the correct OPFOR distance from the transfer poles
Acknowledgments	Button press logs will show if the transfer was acknowledged within 10 seconds

In the surveillance task, the Scanning subtask is the first and most common task performed. Scanning is measured by how much of the environment was seen by the learner over a given amount of time. This can be measured through mouse movement and panning across the screen. It primarily serves as an individual task to make sure that the learner is consistently surveying their assigned area.

The Identify subtask also serves as an individual task. Identifying targets was operationalized as pressing the key associated with identification on the keyboard whenever an OPFOR is spotted. This is the most important of the tasks as it serves as a basis for the others. Participants scan for the purpose of identifying OPFOR. An OPFOR cannot be transferred if it is not first identified.

Transferring and Acknowledging are individual tasks which when paired, constitute a team task. Transferring was operationalized as one team member indicating to another team member where an OPFOR is going to appear. There were two transfer points on opposite sides of the environment (the one-pole area and the two-pole area, shown in Figure 11). Transfer performance was measured in terms of where the OPFOR was when the transfer was initiated. The learner must transfer when the OPFOR is an appropriate distance from the pole boundary: not too close and not too far. The acknowledgement of transfer was operationalized as a button press in response to a transfer initiation. Acknowledgement performance was measured by calculating the time that elapsed between the transfer and acknowledge button presses.

Currently, learners complete the surveillance task as distributed teams: each participant is located in a separate office of a secure laboratory as depicted in Figure 12. The task is completed on desktop computers with wireless headsets, a wrist electrodermal activity (EDA) sensor, and a speakerphone for communication with their team. Additionally, a separate laptop is included for participants to complete the accompanying electronic surveys. A participant designated as Player 1 has a desktop that comes equipped with an eyetracker.

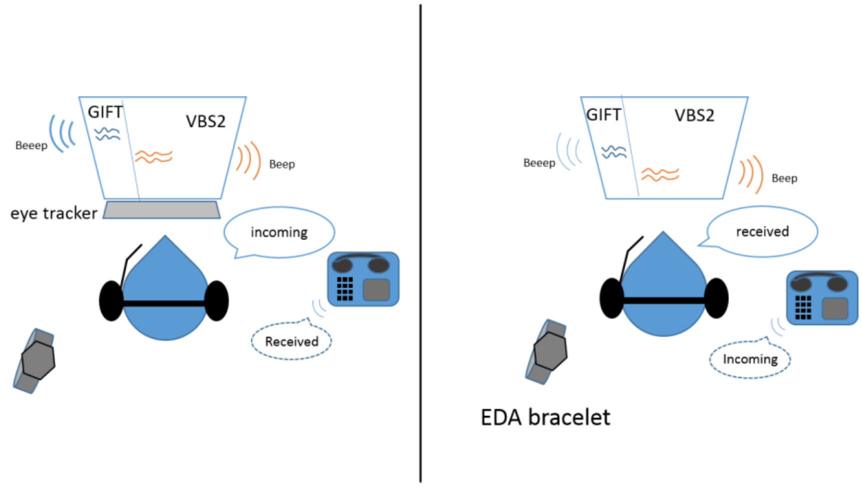

Figure 12: Participant Environment

Prior to arrival, participants complete an informed consent document and a pre-experiment survey. Once they arrive on the day of their session and the teammates meet, they complete a team familiarity survey and proceed to their assigned location as Player 1 or Player 2. Both undergo EDA calibration and training. Player 1 also is calibrated for the eye tracker before the study begins. Within the study, participants complete the task four times and complete two surveys after each trial. Each trial takes 5 minutes to complete, and within a trial, the tasks become difficult as more and more OPFOR emerge. The task is designed to be difficult to complete perfectly. Finally, participants complete a post-experiment survey at the conclusion of the session.

Surveillance Task Testing

To effectively develop the system, a user centered approach was adopted (see Figure 13) (Nielson, 1993). This consisted of gathering requirements needed, designing based on the requirements, implementing the design, evaluating with pilot tests, and iterating. First, requirements were gathered from research described in ISU's previous GIFT publications and ARL's extensive work on team tutoring (Bonner et al., 2015a; Walton et al., 2015a; Sottilare, Holden, Brawner & Goldberg, 2011). From this, the surveillance task was mapped out.

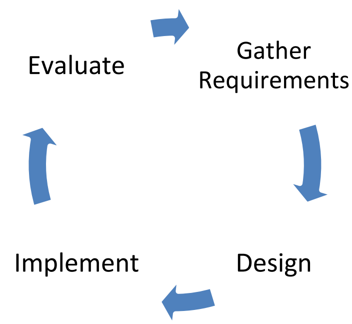

Figure 13: Iterative Design Process

Fourteen pilot tests have been conducted to test the scenario, study environment, and participants' interactions. During these tests, flaws were found which ranged from simple issues such as ergonomics in button placements to the frequency of feedback. For example, in early pilot test, researchers were able to determine an ergonomic improvement to the keyboard key assignments so that participants could make all key presses easily with the left hand while controlling the mouse with the right.

DEVELOPMENT CHALLENGES

Logistic Challenges

Audio: An experimental setup was created in which two teammates, would each have their own laptop with the simulation, and could communicate by voice. This sounded easy enough, but experimentation revealed the audio signals from one teammate's simulation would interfere with the cues of the other teammate's simulation. Wearing headphones for computer audio prevented participants from hearing each other. The participants were separated to help with interference and provide a more realistic training situation, since distributed teams might want to train together. Participants were placed in two different rooms, each with a laptop running VBS2, and made a Google Hangouts voice call between the two rooms. However, as piloting continued, it was clear that this did not solve the problem. Each participant needed to be able to hear the computer audio because it contained information about the simulation as well as periodic beeps from GIFT when feedback was presented. Each person also needed to hear communication from the teammate. But if there was an open audio channel, the audio from the computer of one teammate would go through that channel and interfere with the audio of the teammates' computer. In an initial pilot, with Google Hangouts running as well as the simulation, for example, each teammate heard audio from his or her own simulation, audio from the teammate's computer simulation, and the voice of the teammate. The set up was changed from an audio channel on the computer to a speakerphone call between the two rooms. Headphones were used on one ear only for the computer audio. Therefore one ear of each participant heard the computer, and the other ear heard the audio signal from the speakerphone. This workaround was sufficient for our task, but it seems a little bit clunky, and it is possible that with more complicated team tasks, it may be more difficult to set up audio logistics.

Screen Capture: An additional logistic complexity was capturing a screen recording of each participant's screen while also running GIFT and the simulation on the computer. Screen capturing software such as Camtasia can be CPU-intensive, and running it simultaneously with the complex VBS2 simulation required an especially powerful computer. To fully utilize video and voice recording without overloading the PCs, two Google Nexus cellular phones are placed by the speakerphone in each room to record audio. Currently, Camtasia is used to record Player 2's screen while eye-tracking software records Player 1's.

Simultaneous Start: Another complexity with team tutoring is starting the participants at the same time, so that the systems logging time-stamped data about their behavior have the same time start zero point. To mitigate errors, a three-pronged approach was implemented. First, code was built into the VBS2 scenario so that both participants press the enter key to initialize the scenario. When the scenario first loads, both participants are provided with these instructions via text. To coordinate, the experimenter uses the intercom system to make sure both participants are ready and then instructing both to press the key at the same time via a three second countdown. Lastly, code was added to GIFT so that the GIFT server does not start offering feedback until the client scenario is started. Otherwise, while setting up the task, the GIFT server would be active before the VBS2 scenario, telling learners they are not scanning while the VBS2 scenario had not yet started.

Teammate Communication: Initially participants were to communicate verbally using only a small set of prescribed military-style phrases such as “I have movement in my sector” and “Be advised, two OPFOR transferring to your zone”. This approach would lead to clear communication, and would also allow for easier data coding of communication later, e.g., “Participant 1 said Phrase 3.” However, in pilots, it was discovered that the task was stressful enough that participants did not have the cognitive load to keep to the unnatural prescribed phrases. The mostly undergraduate, non-military participants could no doubt learn the phrases if a significant portion of the experimental time was allocated to training them, but it was decided that the extra time during the study was not worth the potentially cleaner communication data. Thus, they were allowed to communicate openly.

Early pilot participants with military experience did prefer the provided statements over open communication as they were used to the terminology. When allowed to perform open communication, they added to the military phrases for specificity such as close/medium/far when indicating zone transfers.

Piloting Feedback Pre-GIFT Using Wizard of Oz Approach

Because it took multiple weeks to develop the appropriate condition code and feedback rules within GIFT for the Surveillance Tutor, that time was used to conduct pilots of the team experience with the simulation. An aim of the research was to experiment with the feedback statements and feedback timing that was being considering before coding them into GIFT. To pilot the feedback, Google Hangout was used, creating a chat window on screen that was shared by each participant and the researchers. Using this tool, the researchers could stand over the shoulder of the participants and type feedback to the participant as if the tutor were doing so, a Wizard-of-Oz prototyping technique (Kelley, 1984). It was useful to have a textfile open on the researcher’s screen with all the possible feedback statements that were drafted. This method worked well for exploring whether the feedback statements were understandable and possibly too long to fully attend to during the task. However, since the human researchers were playing the role of the tutor, and the actual tutor would respond to a diverse set of encoded conditions in the future, it was difficult to simulate the exact timing and frequency of the future feedback. It was also difficult to simulate rare conditions, i.e., when the participant’s behavior meets two sets of feedback conditions simultaneously, and the tutor might possibly issue two unrelated feedback statements at close to the same time.

It was also difficult to simulate team feedback in our distributed context, because participants were in two different rooms, so even though one researcher was standing over the shoulder of each participant, it was sometimes difficult for them to assess the team’s performance overall since each researcher could see only one participant directly. There was no way for the two researchers to coordinate quickly enough (e.g., “I’ll give the next team feedback, so you don’t have to”). The best approach here was for one researcher to be in charge of team feedback, but that researcher then had to rely on indirect information about the other teammate’s performance. In the future, a GIFT live testing feature might enable similar testing, with feedback statements assigned to function keys that the researcher could press to make the tutor issue a feedback statement. The live testing feature could automatically log all feedback statements made and give the researcher a report afterward, noting data such as “Feedback 1 used 45 times (50% of all feedback), Feedback 2 used 20 times (22%)…” etc.

Eye Tracking Pilots: Too Much Feedback?

One of the challenges with issuing feedback to the participants was that the simulation itself had communication messages that appeared regularly about what was happening within the simulation, e.g., “Target identified” or “Target Transferring at 1 Pole”. These were textual messages that appeared in the simulation window at the lower left and sometimes were accompanied by audio cues. At the same time, feedback in the GIFT window would also appear in the side window, sometimes accompanied by audio cues (Figure 14). It was important for us to figure out whether participants could pay attention to both sets of messages, and whether they understood the different roles of those messages. The messages within the simulation were simply status updates: here’s what’s going on right now. But the messages in the GIFT feedback window were meta-messages, urging behavioral change or encouraging participants.

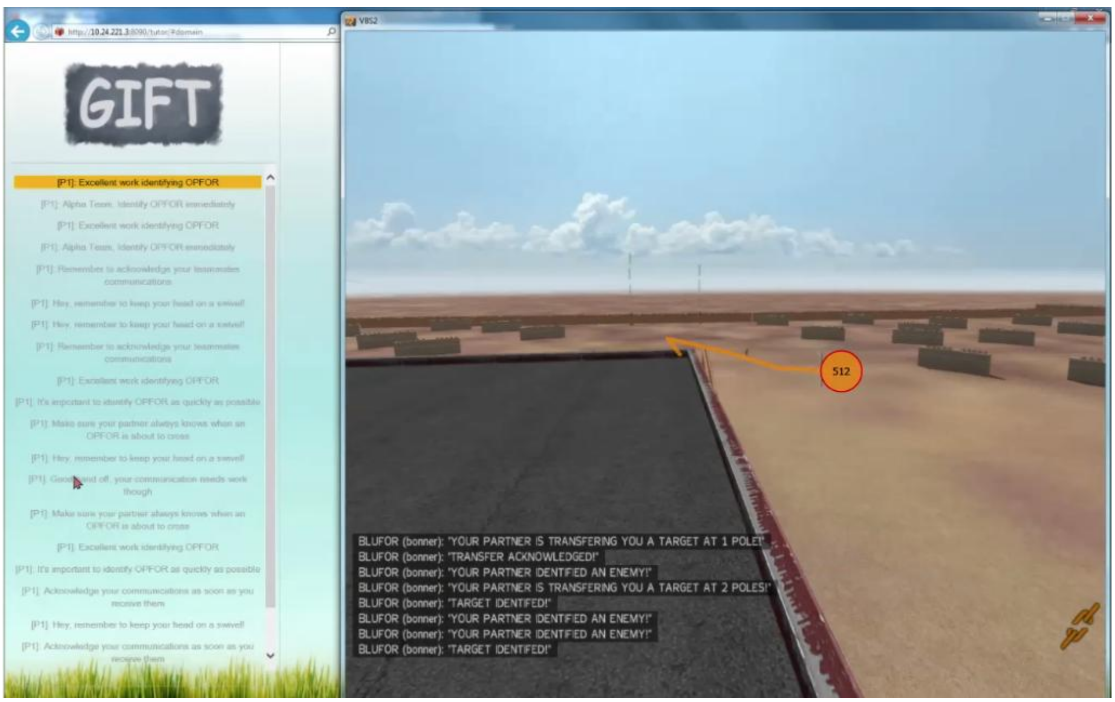

Figure 14: Too much feedback. This picture shows a pilot experiment using eyetracking. After less than a minute of the task, many feedback messages accumulate at left and status updates appear in the scenario window, while participants mostly ignored all written communication and focused on the task. Future pilot experiments decreased feedback and increased font size and readability of messages to lower cognitive load.

It was shown that participants in pilots could attend to both sets of messages if they were short and relatively infrequent. Pilot eyetracking data revealed that when feedback messages were long, and they accumulated down the screen (15+ messages), participants no longer attended the feedback. In later pilots less frequent feedback was explored, as well as presentation variables such as font size, color contrast, and the maximum number of messages to display.

Team Feedback: Public or Private?

In a team setting, feedback given mid-task can generally be directed to team members in four basic ways:

1) **Private**: The individual teammate receives feedback privately about his or her performance, e.g., "Player 1, you need to…"

2) **Public Anonymous**: The entire team receives feedback about each individual's performance anonymously, e.g., after Player 1 makes a mistake, all members receive, "Team, you need to …"

3) **Public Identified**: This could be called the shaming approach. The entire team receives feedback about each individual's performance by name, e.g., after Player 1 makes a mistake, all members receive, "Player 1, you need to…"

4) **Team Feedback**: This feedback is about team performance overall (rather than an individual's performance) and is sent to all team members, e.g., "Team, your frequency of communication needs to decrease."

GIFT currently doesn't support these four modes by default, but for our system it was configured to support modes 1, 2, and 4. One pilot participant was more responsive to public identified feedback, reminded of positive experiences on sports teams. Meanwhile, the partner disagreed, felt publically shamed, and preferred private feedback. Similarly, survey responses across multiple pilots suggest varying efficacy for feedback mode based on previous experiences with teams. Previous research on these approaches yields mixed results (Walton et al., 2015a), suggesting that the best approach may vary by team member's team skills and by the task at hand.

Experimental Design Challenges with Team Tutors

Common challenges for running robust objective clinical studies on team performance are 1) controlling for a similar team experience across multiple consecutive within subjects trials (i.e., handling teams' learning curves and ensuring the task is not repetitive), and 2) controlling for the influence of the team dynamics of particular participant teams (familiarity of members, varying team skills, personalities, etc.). Both of these factors lead generally to a high amount of variance in data collected, which means that studies must include larger sample populations and very simple experimental designs (typically one independent variable) to achieve statistical power. In the surveillance task the first challenge was approached by using multiple similar but different scenarios with the same number of OPFOR. Also, team were discouraged teams from discussing strategy between trials. Doing so might lead to non-linear improvements in the learning curve of the task. To address the second challenge, extensive questions were asked about team experience and team preferences in our surveys, hoping to use those data to factor out impact on our dependent measures during analysis.

A third challenge in team tutor studies, if one is interested in evaluating whether the feedback helped performance, for example, is that different teams may receive dramatically more feedback than others, based on their baseline performance. It is important that the dependent variables, as much as possible, do not depend on the amount or exposure to feedback. In the Surveillance task, after piloting and noticing this challenge, it is this efforts aim to have infrequent but impactful feedback.

Computational Challenges

Challenge 1: Assessment Inheritance

When authoring any intelligent tutoring system, the question arises of the granularity of assessment. In algebra, one might ask, "Does the student know how to solve for a variable?" (higher level) or one might ask, "Does the student know how to divide both sides by the coefficient of x to isolate x?" (lower level). In a simulation tutor, one might assess, "Did the trainee reach the checkpoint on time?" (higher level), or one might assess, "Did the trainee march from A to B, crawl prone from B to C, and then jog from C to D, and arrive at D on time?" (lower level). In these examples, the more general assessment could be derived from the more specific. If you know how the trainee marched, crawled, and jogged, you can answer the question of whether the checkpoint was reached on time. We suggest that this ability to derive higher level assessments is analogous to computational inheritance between parent and child classes. The child assessment (more specific, grounded in concrete behavioral markers) is derived from a parent assessment (higher level, focused more on overall performance).

The challenge in a team tutoring context arises because there are high level team measures that one would like to identify that seem to have no child assessment from which to draw information. In the surveillance task, for example, it is important that the team be good at identifying OPFOR. Identifying can be a team measure, because it is beneficial and informative to compare whether Team A vs. Team B is better at identifying. That team measure for identifying (parent assessment) is likely a simple function of individuals' identifying performance (child assessment), e.g., a weighted average, so team identification is not difficult to assess. However, with the team construct of backup behavior (to what extent does one teammate notice that the other teammate needs help temporarily and pitch in to offer support), another parent assessment, there is no child assessment at the individual level that one can use to provide detail for the team measure. Instead, the team measure must be separately assessed using its own behavioral markers which are likely separate from what is being measured for individual performance.

In GIFT, for the surveillance task, a DKF file exists for each player and a separate DKF file exists for the team, so that there can be individual assessments and team assessments as needed. This approach does not scale well, because for a team of five members, if you want to assess individuals, interactions of pairs of teammates, trios of teammates, quartets of teammates, and the entire team of five, you would need 30 DKFs. If you just wanted to assess the individuals and the team, you would need six DKFs. In either case, it would be attractive if GIFT facilitated the assessment inheritance concept so that a team DKF measure could be a parent of the individual DKFs when appropriate, so that code would not have to be redundant within DKFs.

Challenge 2: Length of Assessment Window

When team members attempt a task, they are immediately assessed. That moment is designated as an event level assessment. In GIFT's standard assessment framework, an event is evaluated as Below Expectation, At Expectation, or Above Expectation. However, for the experiment to have more granularity for the assessment was desired as well as in what would cause the individual’s overall state to change. Therefore rules were written based on an individual’s assessed events that would allow us more flexibility in state changes, and provide an overall state of Below Expectation, At Expectation or Above Expectation. For example, it might be that if an individual has five consecutive Above Expectation events, then the individual's overall state for that task can be set at Above Expectation.

This approach to assessing an individual's state (or a team's state) based on a historical moving window of assessment events is a key concept that feels natural to want to use within assessment, but is not currently built into GIFT. In the surveillance task, different assessment windows were initially specified for different tasks and different states. E.g., for an individual to drop from At Expectation to Below Expectation in the Identify task, the individual must miss three consecutive OPFOR (fail three times at the Identify task, earning a Below Expectation event on each one). To move back up to At Expectation, the individual must achieve five At Expectation events. These thresholds of three and five are arbitrary, however, and the thresholds are different in different tasks. They are continuously adjusted throughout the pilot process.

Challenge 3: Team Feedback Rules

Independent of the intelligent tutoring software platform to be used (GIFT in this case), authoring team rules can be difficult because the complexity of anticipating the multiple possible team interactions. Also, a team's performance is not always a linear sum of the individuals' performances. The details of these challenges arise from the behavioral markers chosen to measure performance.

It is challenging to design effective team rules by themselves in GIFT without including individual rules. Since the transfer and acknowledge tasks are evaluated together, it is not necessarily an effective team evaluation of actions, but instead a series of individual actions completed in sequence.

The team is graded on whether the individuals did their part. For example, a good sports team can pass or score a point, but it is not a rich picture of teamwork. A trainer or coach is able to evaluate how an individual on a team completed tasks to reach a team goal, but can also determine how the team can work together to be more effective. Maybe one player needs to slow down to meet the needs of the others despite individually performing well. Even though Player 2 is always on time with their transfers, maybe Player 1 is at times overwhelmed and late acknowledging due to workload.

An example of straightforward authored individual rule is below. This rule that indicates that if an individual is currently Above Expectation, but based on their recent past performance is considered At Expectation for the majority of assessments, then they should be shifted to the At Expectation state and provided the appropriate feedback.

```
//Scanning rule for Individual:
//If individual state = Above and majority of events in window are At,
//then drop to At state and get At feedback.

IF state_scan = "Above" AND scan_score(scan_window) > (drop_threshold/2)
THEN:
 state_scan = "At"
 give scan_at_state feedback
```

Team rules are more complex than individual rules, and rely on the current state assessment with individual team members, as well as those team members' recent actions (event assessment). A team rule example can be found below. In our case it is accounting for the state of two members. In the case of a larger team the rule would be more complex. These rules assess the overall state of team communication by examining the transfer and acknowledging the states of the team members.

```
// Communication rule for Team:
```

```
// If either player has Above state for transferring, and
// the other player has Above state for acknowledging, then
// set team's communication state to "Above."
If player(any).transfer_state = "Above" and
   player(other).acknowledge_state = "Above" THEN:
       Team_communication_state = "Above"
       Give team_communication_above_feedback
```

Recommendations

Based on these challenges, we have several recommendations for future versions of GIFT. GIFT should allow for more extensive logging of events within the learner's interface. Currently, GIFT logs all events within GIFT (e.g., messages), but it requires custom software development to log button presses or mouse events in the third-party software during the GIFT session. For example, in our surveillance task, we developed code to record VBS2 button presses and turn them into GIFT messages so that they could be logged by GIFT. In our scanning condition, it would have been beneficial to have a way to track each time the learner moved the mouse instead of the position of the camera, but that was beyond the scope of our effort. It would also be helpful to have the GIFT feedback more tightly integrated with the software platform to provide feedback directly in the learner's field of view instead of being located off to the left. As previously mentioned, the inclusion of a live test feature would help pilot testing. Additionally, a plugin for multiple open source platforms (e.g., Unity) would allow for wider use of the tutor. Finally, team tutoring should expand to larger teams with more complex roles (Bonner et al. 2015). The DKFs should be reorganized to prevent redundancy with regard to team and individual assessment. Beyond military tasks, other avenues such as education and corporate teams could be leveraged.

CONCLUSIONS

Several challenges have been encountered in our two years of developing with GIFT but have been able to overcome a majority of them. While GIFT is a robust system, there are additions that could be made to improve its functionality for team tutoring. Team tutoring is inherently difficult to design for, particularly in a domain-independent framework. There needs to be flexibility in the approaches that are taken to construct assessments for both individuals and teams, as different domains, varying team sizes, and varying interdependencies of responsibilities may be present depending on the specific task to be taught. Feedback types and timing are very important to team tutoring, and this should be taken into consideration when authoring for teams. The work demonstrates lessons learned and ways that GIFT was utilized when developing a team Surveillance tutor. It may be helpful to expand GIFT's capabilities for assisting team tutoring design as work was included to incorporate features which are not currently present. While designing team intelligent tutoring systems is a hard problem, it is one that is achievable.

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